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PROCEEDINGS

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Wednesday	Thursday
Sept. 8	Sept. 9
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Conservation Tillage 2004

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ADOPTING LESSONS FROM BRAZIL FOR CONSERVATION TILLAGE IN THE SOUTHEASTERN USA

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ABSTRACT

Many soils of the southeastern USA are degraded from continuous cropping of cotton (*Gossypium hirsutum* L.) and subsequent soil erosion and loss of organic matter. Brazilian research has shown the benefit of intensive rotations, high-residue cover crop production, and conservation tillage to improve soil productivity. In the southeastern USA, we have adapted the Brazilian model to specific soil types; to manage soil compaction, improve soil quality, and reduce risks from short-term droughts. For all soils, the use of high-residue producing cereal and/or legume cover crops is the crucial management component. For silty-clay soils, a cereal cover crop is used with non-inversion under-the-row tillage in fall. For coarser-textured coastal plain soils with root-restricting compacted layers, the non-inversion tillage is accomplished in spring, as these soils reconsolidate with winter rainfall. Coastal plain soils allow greater diversity in choice of cover crops. Refinements for the systems include adjusting planting dates of cover crops and cash crops to maximize residue production, modifying equipment to perform in heavy residue, and more recently, the use of Real-Time Kinematic Global Positioning System (RTK-GPS) guidance systems for equipment. These practices have played a key role in the dramatic increase of conservation tillage adoption in the southeastern USA.

INTRODUCTION

Historical agricultural mismanagement of the soils in the southeastern USA has resulted in soil degradation, with consequent negative environmental and economic impacts. The climate in the region is humid subtropical and soils (mainly Ultisols) are heavily weathered. The use of conventional tillage, lack of crop rotation [especially monoculture of cotton (*Gossypium hirsutum* L.], burning or incorporation of crop residues, and cultivation of sloping and marginal lands has resulted in soil erosion and the loss of organic matter. Government programs have made great progress in addressing the problem of soil erosion, but until recently, the "hidden" problem of soil organic matter loss and resultant reduction in soil productivity has not been the focus of government and educational programs. In times of low commodity prices and reduced economic growth, farmers are reluctant to allocate labor, time, thought, or money to solve a problem unless it produces an immediate economic benefit.

Until very recently, cotton producers in the United States lagged behind corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] producers in adoption of conservation tillage. As with these crops, inadequate management and fewer weed control options played a role in slowing adoption of conservation tilled cotton. Special considerations for cotton also reduced the adoption rate. Achieving adequate cotton emergence and plant populations in conservation tillage systems can be a problem due to: 1) cooler and wetter soil conditions in conservation tillage compared to conventional tillage, 2) cotton=s sensitivity to seedling diseases like *Rhizoctonia, Pythium,* and *Fusarium,* 3) sensitivity of cotton seedlings to allelopathic activity associated with cover crops, 4) poor seed-to-soil contact caused by planting equipment problems, and 5) soil compaction and crusting in degraded soils with low organic matter. Additionally, research has shown that conservation tillage can delay maturity and harvesting; a critical consideration in the more northern areas of the Cotton Belt (north Alabama, Tennessee, Virginia, and northern Texas) with a short growing season, and along the southern Gulf Coast (Alabama, Louisiana, Florida, and Mississippi), where delayed harvesting increases risks of crop loss from tropical storms and hurricanes.

In the USA, cotton has historically been grown in monoculture. Cotton is a low residue crop, generally producing only 2 to 3 t/ha of residue (Reeves, 1994). The lack of rotation for this low residue producing crop means that soils cropped to cotton are especially subject to degradation from erosion and loss of organic matter; therefore there is a critical need that conservation tillage systems for cotton be developed. However, the amount of conservation tillage cotton in the southeastern USA has dramatically increased in the last six years. According to 2002 statistics (most recent data) from the Conservation Technology Information Center, no- tillage cotton in the Southern states grew from 627,000 acres in 1998 to 1,938,000 acres in 2002, a threefold increase (CTIC, 2004). A survey released in 2003 by the National Cotton Council of America (Anonymous, 2003) reported that 57% of the total cotton acres in the Southeast was in no-tillage. Annually, conversion of over 1.31 million acres of cotton in the Southeast saves 10.6 million tons of soil worth $198 million in on-farm and off-site impacts and $39 million in fuel and labor. A number of factors have contributed to this increase, including the use of glyphosate resistant cotton varieties (Roundup Ready® cotton), research to solve problems with conservation tillage cotton, aggressive technology transfer by USDA-NRCS, private agri-business and university extension services, and growers' efforts to reduce production input costs.

When cotton producers initially tried conservation tillage some years ago, they simply eliminated their normal tillage operations, i.e., moldboard plowing or chisel plowing, followed by disking and seedbed leveling prior to planting. They did not use cover crops or crop rotations. In one of three years, this region undergoes a yield-limiting drought. Consequently, yields were reduced 5 to 15% compared to the prior-used conventional tillage system. The yield reduction was generally caused by soil compaction in the degraded, low organic matter soils (0.5 to 1.5 % organic matter); which reduced root growth, decreased infiltration, and increased risks from short-term droughts.

Brazil is a world leader in adoption of conservation practices like no-tillage. Beginning in 1990, researchers, extension specialists and farmers from Alabama and Georgia visited Brazil and Paraguay to see first hand conservation system development and adoption. We adapted the lessons learned from these countries to our soils and crops, especially cotton, which is the major cash crop in the southeastern USA. We focused on ameliorating two main problems in this subtropical region: 1) improving soil quality and reducing risks from short-term drought through the use of cover crops and crop rotation with a high-residue producing crop, and 2) management of soil compaction.

THE BRAZILIAN MODEL

Brazil, Argentina, and Paraguay are leaders in adoption of conservation tillage. Approximately 21% of cultivated land in the USA currently uses conservation tillage, while in Brazil, Argentina, and Paraguay, the adoption rate is 50%, 55%, and 60%, respectively (Derpsch, 2004). Additionally, Derpsch estimates that 90% of the no-tillage in Latin America is long-term or 'permanent' no-tillage, while in the USA, only 25% of no-tillage acreage is considered "permanent"; producers in the USA frequently practice rotational tillage, i.e., no-tillage for 2 to 6 years interrupted by reversion to conventional tillage.

The secret for this success in Brazil and neighboring countries like Argentina and Paraguay has been outlined by Derpsch (2002). Psychological and sociological reasons aside, a key technological difference between Brazil and its neighbors vs. the United States is an understanding that conservation tillage is a *SYSTEM* and not a single practice. Components of this system include the use of green manure cover crops, crop rotation, integrated biological control of pests and weeds, and site-specific solutions to problems (Derpsch, 2001).

Reducing inputs and increasing margins is the driving force for adoption of conservation practices in Brazil and neighboring countries. The drive to adopt conservation practices in Brazil is led by producer-leaders, not government researchers and extension specialists. Producers work together through cooperatives to not only collectively reduce costs of purchased inputs and optimize marketing efficiencies for their commodities, but they also form and finance their own applied research and technology institutions. Additionally, producers have developed very effective local, regional, and national No-Tillage Associations. Producers pay a fee based on the acreage of their farms to support the research foundations. The technologies developed are customized for both small and large producers (Figs. 1-3).

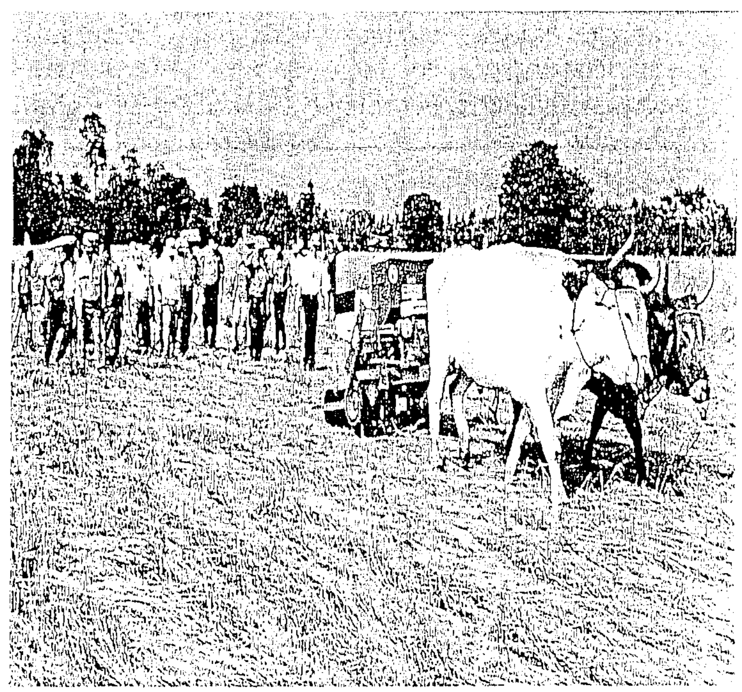

Fig. 1. Conservation technologies in southern Brazil are developed for both small and large farmers. An animal drawn no-till planter capable of planting in heavy cover crop residue is demonstrated at a field day.

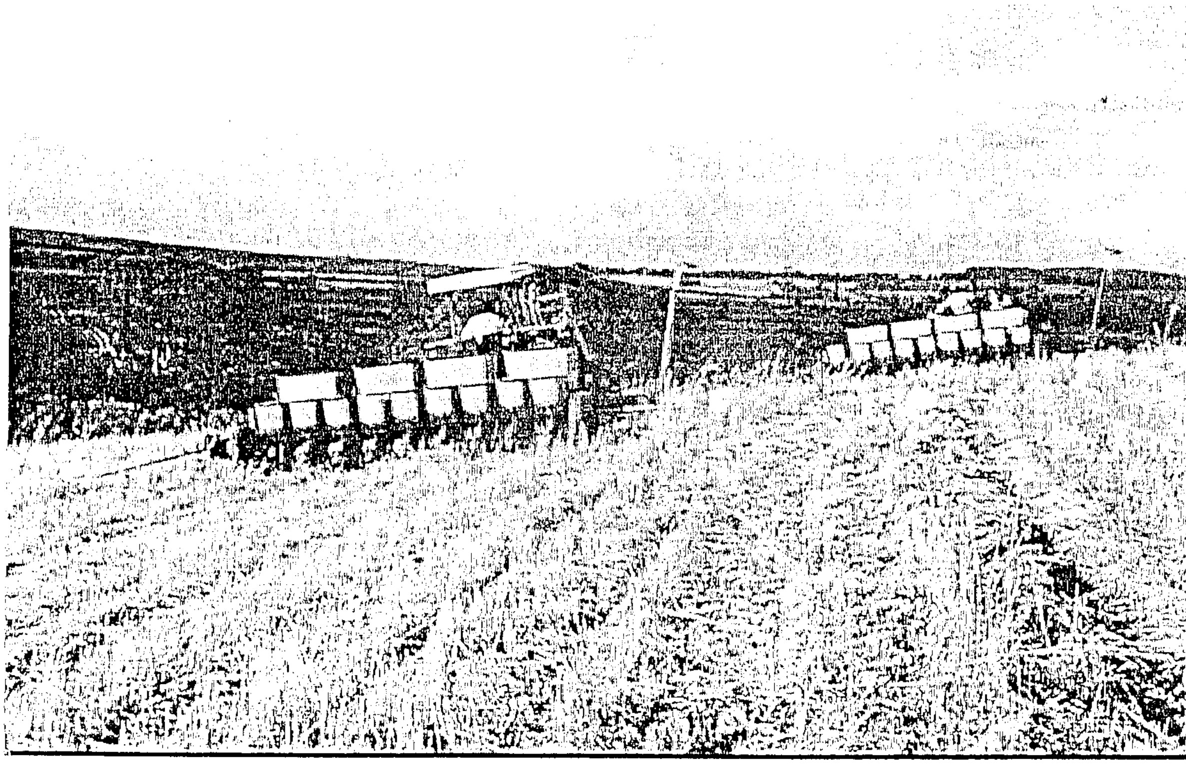

Fig. 2. Conservation technologies in southern Brazil are developed for both small and large farmers. No-till planting soybean in the rolling hills of Paraná, Brazil. The rolling topography restricts use of very large planters. Paraná state accounts for about 2% of the cultivated acreage in Brazil, but roughly 20% of Brazil's grain (soybean and corn) production.

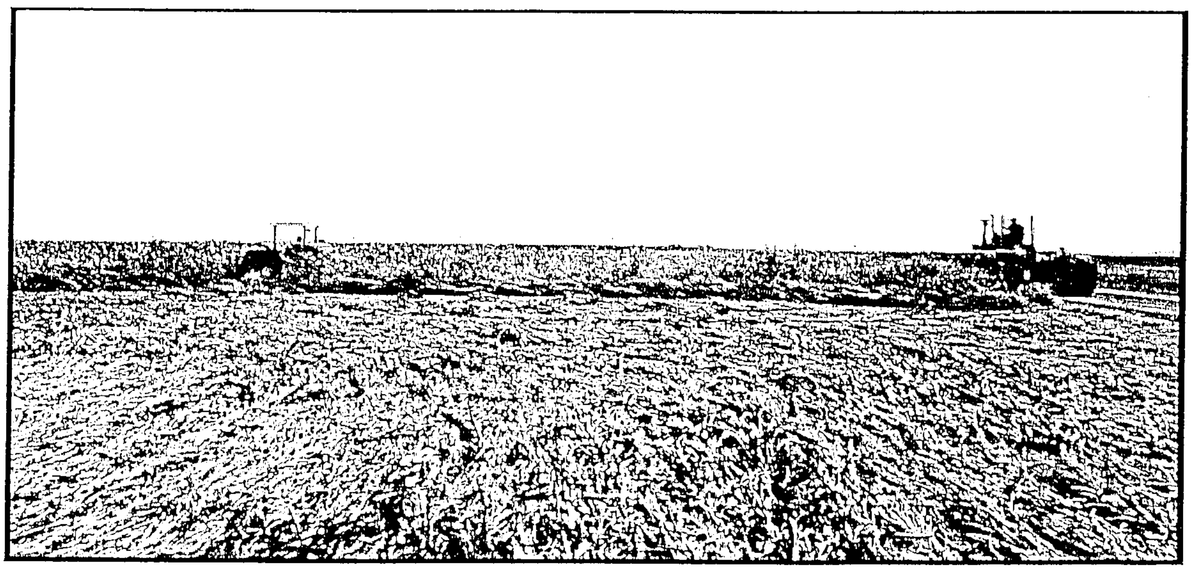

Fig. 3. Conservation technologies in southern Brazil are developed for both small and large farmers. Laying down a pearl millet cover crop on a large farm in the 'Cerrado' region of central Brazil with a heavy chain and two tractors. The Cerrado area consists of about 250 million acres of savanna with a bimodal rainfall pattern. Brazil is rapidly expanding production of cotton and soybean in this area. Farms in this region are several thousand acres in size.

Residue production is critical to successful conservation tillage systems. However, the need for residue is climate dependent (Fig. 4). In warm humid climates, rapid decomposition of soil organic matter requires maximum cropping intensity and the use of cover crops to 'stay ahead of the curve', i.e., to fix carbon through photosynthesis faster than the rate it can be oxidized by soil microbes. In drier and/or cooler climates residue decomposition and the rate of loss of organic matter is not as great and the need to produce residues in the system is reduced. The soils and climate in southern Brazil are similar to that of the southeastern USA, and we effectively adapted the main lesson from this region to crop production in the Southeast. This lesson was that high-residue producing cover crops were critical to making conservation tillage work in our region.

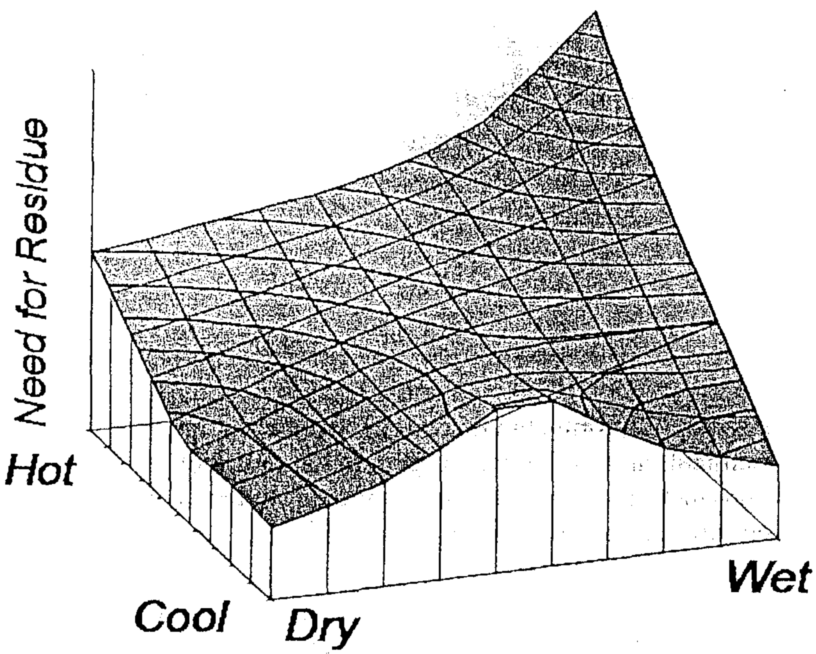

Fig. 4. A stylized model illustrating the need for crop residues to sustain the soil resource as affected by climate (derived from Stewart et al., 1991). The warm-humid climate of the Southeast requires maximum production of residue through cropping intensity, cover cropping and rotations with high-residue producing crops like corn (top-right on model). The need for residue production is less in warm semi-arid regions, like California (left-rear on model).

Soil organic carbon (SOC) or soil organic matter (SOM) is the basis of soil quality for most soils. The relationship between soil carbon and soil organic matter varies with soil type, but generally soil organic matter can be calculated by multiplying soil carbon by a factor ranging from 1.7 to 2. Soil carbon is integrally tied to soil quality indicators (Doran, 1994; Reeves, 1997) and forms the center of a web linking soil physical, chemical, and microbiological indicators of soil quality and productivity (Fig. 5).

In the Southeast, cover crops and cropping intensity are the key components of the Brazilian system for making conservation tillage work. Crop residues contain about 40% carbon, and this carbon is crucial to maintaining or even increasing soil carbon.

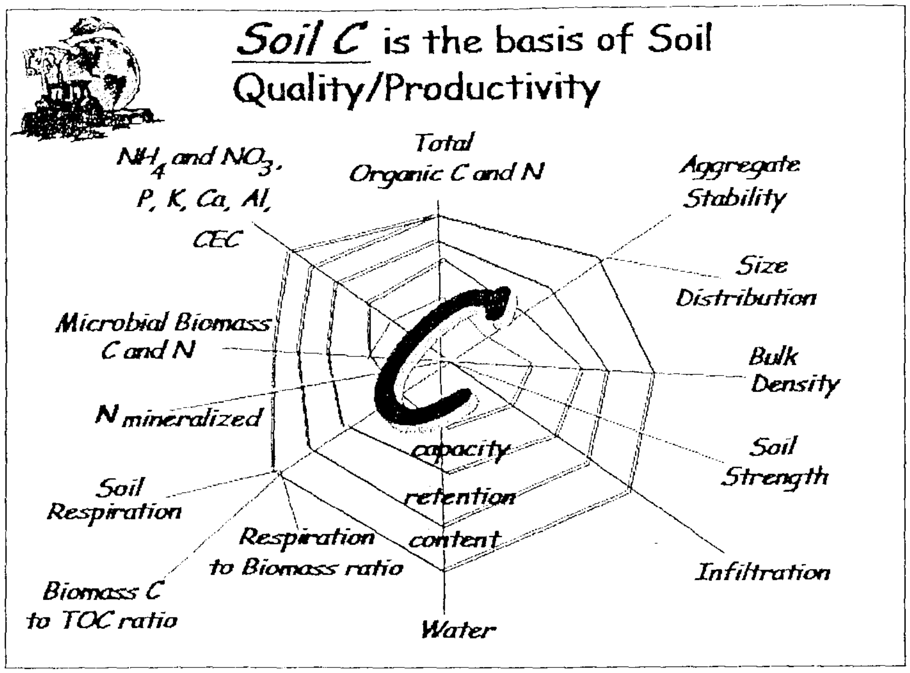

Fig. 5. Soil carbon (C) forms the linkage for the web of interrelated soil physical, chemical, and biological properties that are indicators of soil quality and productivity. Indicators are derived from Doran et al., 1994. Crop residues are critical to production of soil C.

Increasing soil carbon improves soil productivity in the long-term, but for the "humid" Southeast, the greatest and immediate benefit from cover crop residues is water conserving mulch to sustain crops through short-term droughts common to the region. In field studies, we obtained 95% infiltration from a simulated 2-inch rainfall with conservation tillage and cover crop residues, compared to 60% infiltration with no-tillage and cover crop residues removed, and 25% infiltration with conventional tillage when cover crop residue was incorporated.

Cotton is grown in two main physiographic areas in the southeastern USA; the Limestone Valley and Piedmont in the northern part of the region, and the Coastal Plain in the southern part of the region. Soils in the Limestone Valley and Piedmont are predominately clay, while those in the Coastal Plain region have a high sand content. The variation in soil type, as well as the difference in climate between the two regions requires a similar but different conservation system, both relying on lessons learned from the Brazilian model.

CONSERVATION TILLAGE FOR HEAVY CLAY SOILS

The Tennessee Valley region of north Alabama is a major cotton producing region in the Limestone Valley. Soils are derived from limestone, and textures range from silt loam to silty clay loam. Over 60% of the land is classified as highly erodible. Continuous monocropping of cotton with conventional tillage for over 100 years has resulted in soil degradation from erosion and loss of organic matter. When producers initially switched to conservation tillage some 9 years ago, they eliminated their normal tillage operations, i.e., moldboard plowing in the fall and disking and seedbed leveling in spring prior to cotton planting. No cover crop or crop rotation was used. Consequently, yields were reduced 5 to 15%

compared to the prior conventional tillage system (Burmester et al., 1993). The yield reduction was suspected to be caused by soil compaction in the degraded, low organic matter soils (0.7 to 1.5 % organic matter), which reduced root growth, decreased infiltration, and increased risks from short-term droughts.

After 6 years of research, we developed a conservation system for the region which makes conservation tillage competitive with the previous conventional tillage systems used by the growers (Schwab et al., 2002). Building on knowledge gained from Brazilian researchers and producers, the key to the system is the use of a high-residue producing rye (*Secale cereale* L.) cover crop coupled with *non-inversion* tillage in the fall to reduce soil compaction. The positive effect of including a cover crop in the no-tillage system on reducing soil strength can be seen in Fig. 6a. The advantage of the cover crop is to increase infiltration and conserve soil water; soil strength is reduced and root growth is increased when the soil remains wetter. Additional reductions in soil strength with non-inversion tillage using a bent-leg (Paratill®) or parabolic subsoiler in autumn just prior to planting the cover crop are illustrated in Fig. 6b. The residual effect of the fall tillage carries over to the following growing season. Although cotton responses to tillage varied by year and rainfall distribution, the inclusion of a rye cover crop made conservation tillage yields competitive with the conventional tillage system used by the growers, and non-inversion fall tillage increased yields even more (Fig. 7).

Additionally, the rye cover crop dramatically increased soil organic matter in the top 2-inches of soil (Fig. 8). Although the increase in SOM is limited to the surface two inches of soil, this is important as the soil surface controls infiltration in these low organic matter degraded soils. We measured soil organic matter after 5 years in the various tillage systems. The conventional tillage system, which consisted of fall chisel plowing and disking, followed by spring disking and field cultivation, averaged about 1.2% SOM throughout the plow layer. No-tillage increased SOM to 2% but only at the top 2-inches of soil. Including a rye cover crop with no-tillage increased SOM to 4% in the top 2-inches of soil, while fall paratilling with a rye cover crop and no-till planting increased SOM to 3% in the top 2-inches, with a slight increase in SOM from 2-4 inches compared to strict no-tillage. The paratill likely increased rooting and provided a redistribution of SOM deeper in the profile from crop roots compared to strict no-tillage.

We also modified planting equipment by adding residue managers (row cleaners) and spoked seed closing wheels (Fig 9). The row cleaners remove heavy accumulations of residue over the seed row, reducing "hair-pinning" of residue. This increases seed-to-soil contact, facilitates proper seed depth placement, and helps to warm the soil over the row. The heavy clay soils are readily compacted at the seed placement zone (side-wall compaction) by solid seed closure wheels. The spoked closures firm the soil over the seed without causing side-wall compaction.

CONSERVATION TILLAGE FOR COASTAL PLAIN SOILS

Soils of the US Southeastern Coastal Plain are sandy, with low water-holding capacity, and typically possess root-restricting hardpans (Kashirad, et al., 1967; Campbell, et al., 1974). Consequently, in-row subsoiling (40-cm depth) prior to planting is required to produce economically sustainable yields (Reeves and Touchton, 1986; Reeves and Mullins, 1995). The conservation tillage

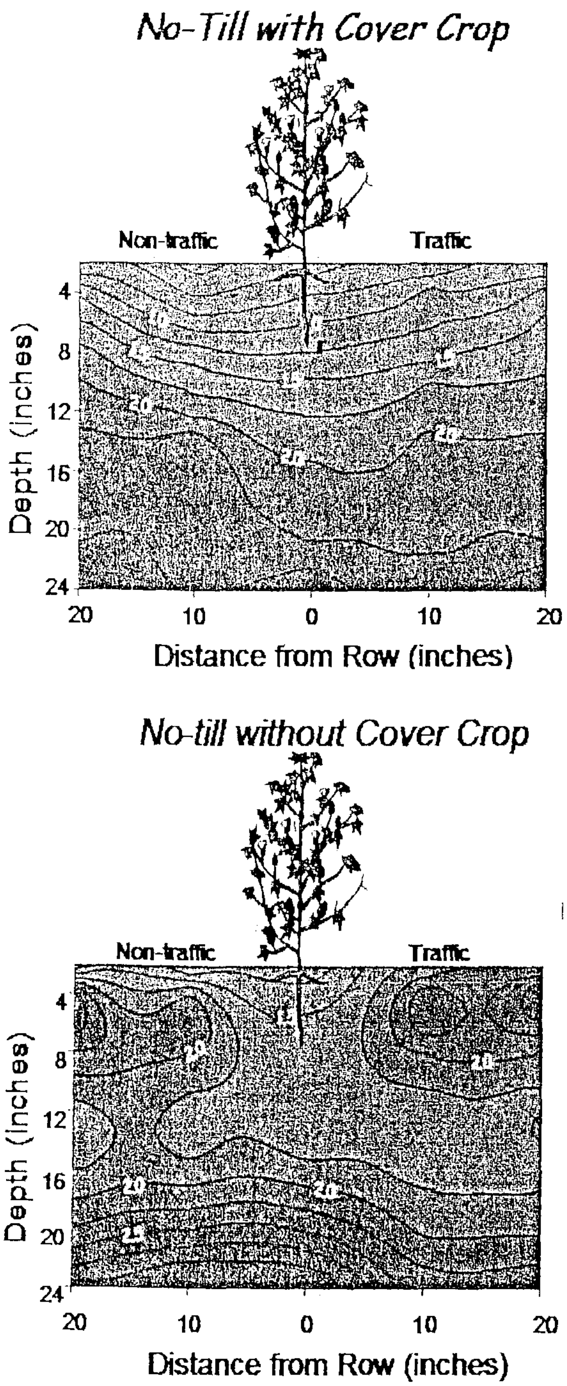

Fig. 6a. Soil strength in no-tillage cotton on a silty-clay loam soil in north Alabama. (Top) no-tillage without a cover crop. (Bottom) no-tillage with a rye cover crop. Contours reading 20 bars or greater indicate root-limiting soil strength.

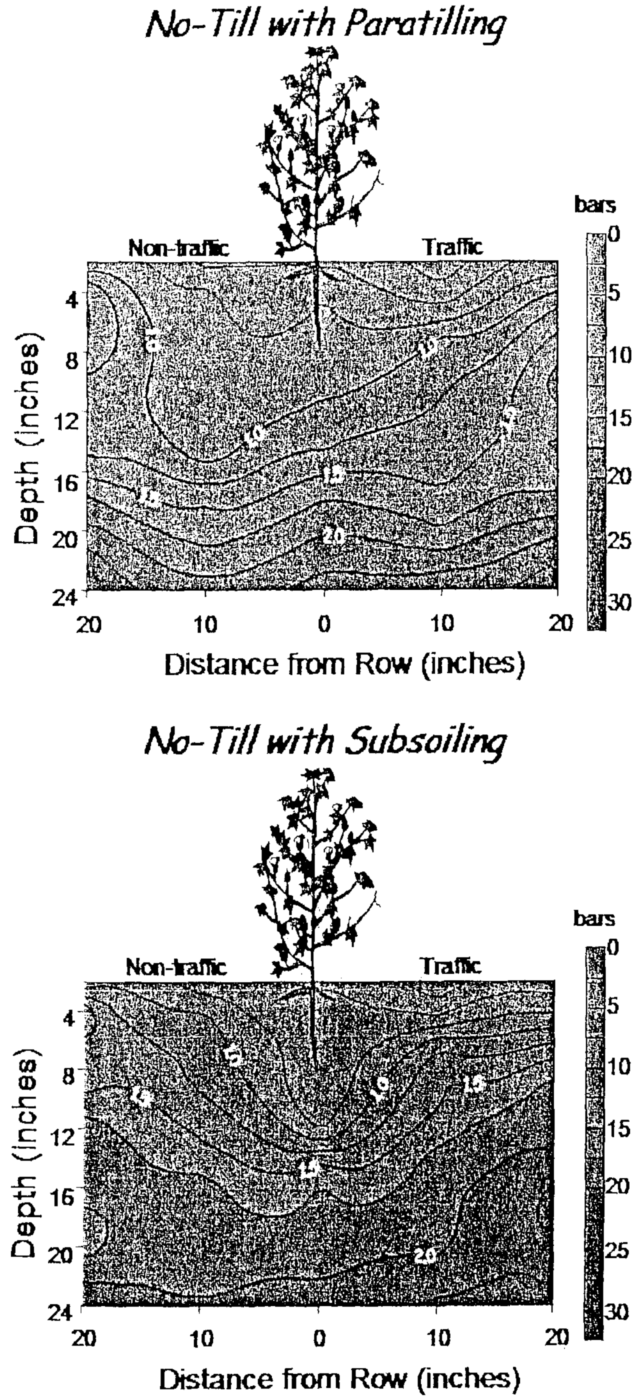

Fig. 6b. Soil strength in no-tillage cotton on a silty-clay loam soil in north Alabama. (Top) no-tillage with fall paratilling and a rye cover crop. (Bottom) no-tillage with fall in-row subsoiling and a rye cover crop. Contours reading 20 bars or greater indicate root-limiting soil strength.

system of choice on these soils is termed *strip-tillage*. Again, borrowing ideas from Brazilian and Paraguayan researchers, we modified this system to enhance water holding capacity, weed control, and productivity. A cover crop of rye or black oat (*Avena strigosa* Schreb.) is grown and terminated with a combination of a roller knife (rolo-faca) and glyphosate or paraquat (Ashford and Reeves, 2003). In-row subsoiling is accomplished using a narrow-shank subsoiler with pneumatic tires to close the subsoil slot with minimal soil surface disturbance (Fig.10). Alternatively, we use a Paratill® equipped with a roller to disrupt the tillage pan and roll the cover in one operation. Cotton is planted into the rolled cover crop mulch 4 weeks after rolling. Using this system, in a 3-year study, the increase in cotton lint yield compared to the traditional strip-tillage system without a cover crop was worth an additional $220/A/ year.. The yield increase was due to

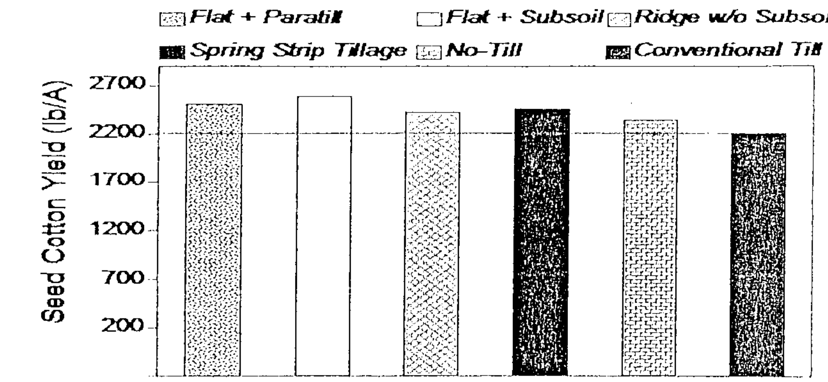

Fig. 7. Mean yields (5-years) of cotton grown with various tillage systems in north Alabama on a silty-clay loam. Flat = cotton planted on level ground, Ridge = cotton planted on raised beds, Spring Strip Tillage = shallow (6-inch) in-row zonal tillage with anhydrous knife and coulters accomplished in spring before planting, Conventional Till = chisel/disk in fall, disk and field cultivate in spring. Paratilling and Subsoiling were done under-the-row the previous fall before cotton planting. All tillage systems used a rye cover crop, with exception of conventional tillage.

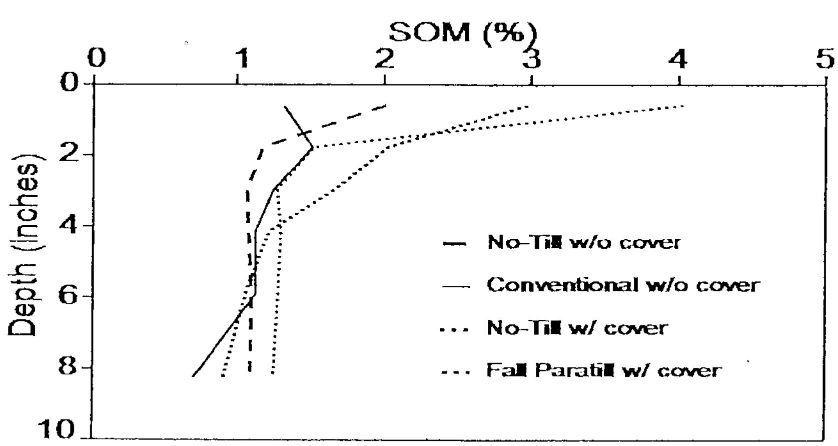

Fig. 8. Soil organic matter (SOM) after 5-years from a silty-clay loam cropped to cotton in north Alabama as affected by tillage system and a rye cover crop. w/ = with cover crop, w/o = without a cover crop. Conventional tillage is chisel/disk in fall, disk and field cultivate in spring. Non-inversion deep tillage by paratilling was done in fall before planting rye cover crop, cotton was planted no-till.

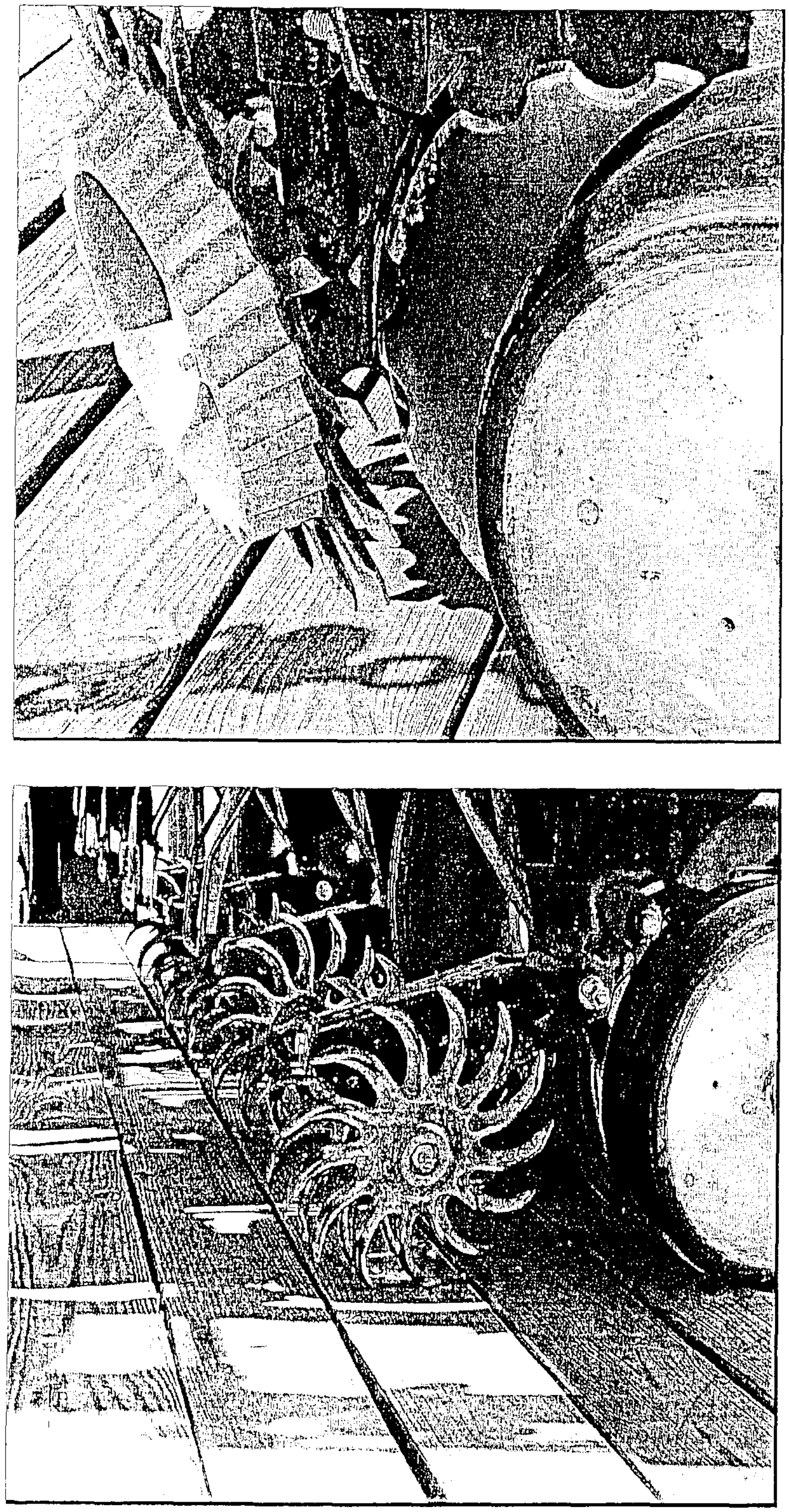

Fig. 9. (Top) residue managers to clear heavy residue from seed zone. (Bottom) spoked closing wheels reduce side-wall compaction in wetter, more compacted no-tillage soils.

improved water conservation on these drought-prone soils.

Growers have adopted this system and are making it work. A grower designed and fabricated roller is shown in Fig. 11. Jimmy Brooks farms several thousand acres in southern Alabama in the coastal plain. He is shown rolling a dense rye cover crop. He follows that with in-row subsoiling with a subsoiler like in Fig. 10 and then no-till plants. He uses a GPS guidance system to stay over the in-row subsoil channel and to maintain his row positions. Lamar Black in eastern Georgia was an early adopter of the system. Fig. 12 shows the roller Mr. Black made rolling down his rye cover crop. His rolled and killed rye ready for planting is shown in Fig. 13 and the resulting cotton stand is shown in Fig. 14.

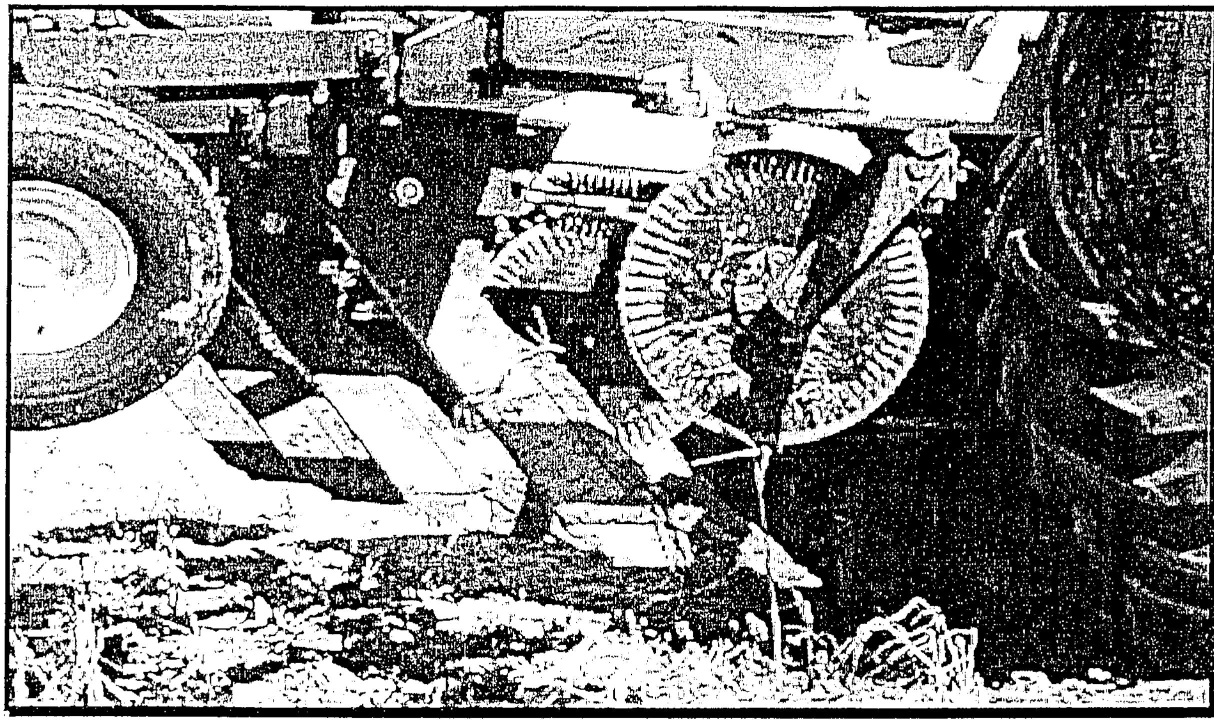

Fig. 10. Narrow-shanked in-row subsoiler used to break compacted layers in degraded soils converting to no-tillage. Coulter on front cuts residue and pneumatic closing wheels firm subsoil channel without surface residue disturbance.

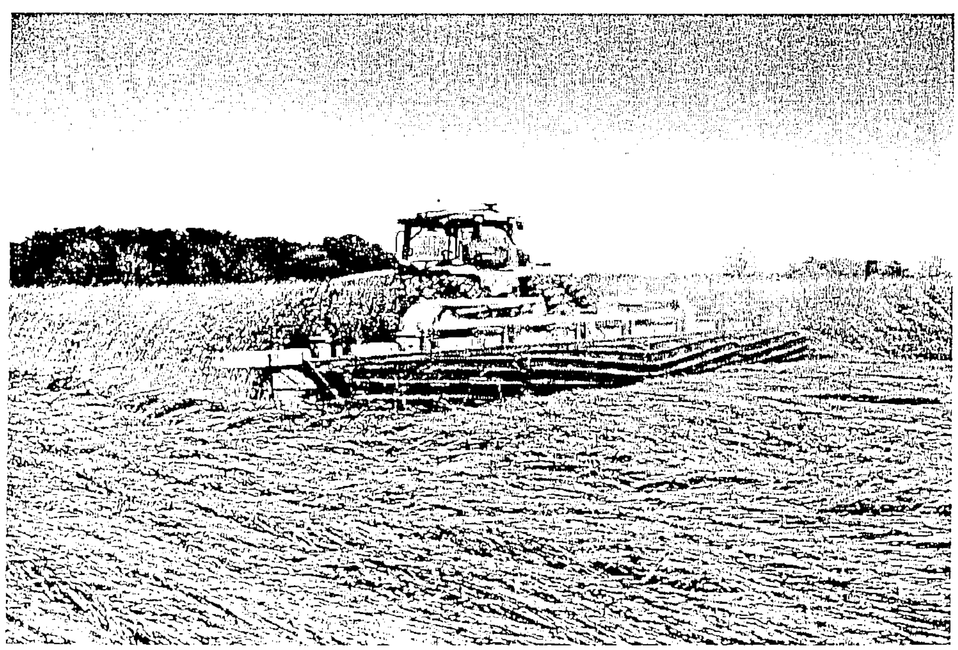

Fig. 11. Jimmy Brooks, producer from southern Alabama, rolling rye cover crop. Mr. Brooks had the roller custom made.

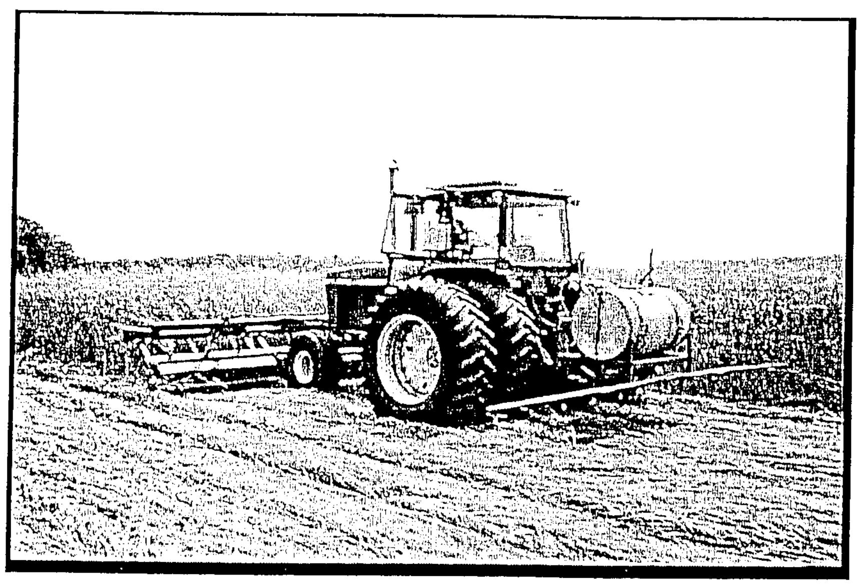

Fig. 12. Cover crop roller developed by Lamar Black, Tilmanstone Farms, Millen, GA. Roller lays down and crimps rye cover crop, sprayer is applying glyphosate at reduced rate to terminate cover crop 4 weeks before cotton planting.

Fig. 13. Lamar Black, Tilmanstone Farms, Millen, GA, illustrating mat of rye cover crop residue covering soil surface following termination with roller 4 weeks before cotton planting; field ready for cotton planting.

Fig. 14. Strip-tilled (no-till plus in-row subsoiling) cotton planted into a rolled rye cover crop by Lamar Black, Tilmanstone Farms, Millen, GA. Rye increases infiltration and reduces evaporation of rainfall and irrigation, and provides mulch for weed control.

CONCLUSIONS

The Brazilian model developed for warm humid climates and degraded soil uses a *SYSTEMS* approach, with cropping intensity and cover cropping the cornerstone of the system. Researchers, extension specialists, and USDA-NRCS personnel have worked with producers and agri-business to successfully refine the system for the Southeastern USA. This has contributed to the 57% adoption rate for no-tillage cotton in the region. The system provides residue and increases soil carbon or SOM in the surface soil, which is critical for increasing infiltration and water conservation. The result is less risks from short-term drought and increased profitability for producers in the Southeast.

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